DEVELOPMENT OF A LIVESTOCK WEATHER SAFETY MONITOR FOR FEEDLOT CATTLE

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ABSTRACT. *Summer heat can result in stressful conditions for Bos taurus feeder cattle, and in extreme instances these conditions can be fatal. The feedlot operator has management options available to him if he is aware of current and impending heat-stress events. Many livestock production facilities exist in environments that may differ significantly from the conditions at the closest weather station. There is a need to provide producers with heat stress information from an on-site real-time weather monitoring system. A monitoring device, referred to as a Livestock Safety Monitor (LSM), was designed around a commercial weather station (Vantage PRO by Davis Instruments, Hayward, Calif.) that was coupled to a microcomputer (TFX-11, by Onset Computer, Pocasset, Mass.). The weather station collects current weather data including temperature, humidity, wind speed, and solar radiation. The weather information is transferred to the micro-computer where the weather data is used to generate a physiologically-based stress factor. The estimated values alert the operator of current conditions that include: (1) normal, (2) alert, (3) danger, and (4) emergency categories. This article will summarize development and operating experience using the LSM.*

Keywords. *Feedlot, Heat, Weather, Threshold, Temperature, Humidity.*

Cattle are remarkable in their ability to cope with environmental stressors and within limits (solar, temperature, humidity, and wind speed) can adjust physiologically, behaviorally, and immunologically to minimize adverse effects (Hahn, 1999). High ambient temperature (t_a) and humidity (relative humidity, RH), in combination with solar radiation (SR) and low air speed (WS), can exceed stressor limits and result in productivity losses and even death of the animal (Hahn and Mader, 1997; Gaughan et al., 2000; Lefcourt and Adams, 1996; and Mader et al., 1999). Recognizing the potential severity of a heat stress event and providing access to stress-reducing measures for vulnerable animals can reduce performance and death losses.

One method of estimating heat stress severity has been the Livestock Weather Safety Index (LWSI; LCI, 1970) which was used by the U.S. National Weather Service for advisories (USDC-ESSA, 1970) The LWSI is based on a derived statistic called the Temperature Humidity Index (THI) (Thom, 1959):

$$THI = t_{db} + 0.36\ t_{dp} + 41.2 \quad (1)$$

where

t_{db} = dry-bulb air temperature (°C)

t_{dp} = dew-point temperature(°C)

The THI defines stress indices as: Normal, ≤ 74; Alert, 75-78; Danger, 79-83; Emergency, ≥ 84. For additional discussion of the THI and its applicability, see Hahn (1995). The THI inherently lacks the effects of WS and SR and is not directly based on an animal's physiological response. A heat stress prediction model based on physiological responses of livestock is desirable. A variety of response measures could be considered, such as: behavioral observations, rate of gain, feed intake, immune function, core body temperature, and/or respiration rate. Of these response measures, respiration rate (RR) provides a noninvasive and practical assessment of heat stress in feedlot cattle (Brown-Brandl et al., 2005b; Hahn et al., 1997; Mader et al, 1999; Gaughan et al., 2000; Mitlohner et al., 2001; Eigenberg et al, 2005). Furthermore, an equation to predict RR based on ambient conditions (t_a, SR, WS, and RH) was developed from a 2001 summer cattle study (Eigenberg et al., 2005). The estimated RR is based on the physiological response of cattle to a wide range of environmental conditions; this predictor should better reflect animal response when compared to a derived statistical model such as THI.

Many livestock production facilities exist in environments that differ significantly from the conditions at the closest weather station. Furthermore, advisories for the Livestock Weather Safety Index (LWSI; LCI, 1970), developed by the transportation industry (based on THI) as a severe weather warning for producers, is no longer available over commercial radio/television broadcasts for most livestock production areas. There is a need to take advantage of the previously developed scientific RR knowledge and develop a livestock stress monitor based on animal response for producers to use as a decision tool in managing the feedlot.

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Objective

The objective of this experiment was to develop a monitoring system for producers using local weather data and estimated heat stress response of feedlot cattle as an aid to heat stress management.

Materials and Methods

The Livestock Safety Monitor (LSM) had two requirements: a weather station that would supply local weather conditions and a readout device located within the producer's office. The functional system consists of four major components: (1) a commercial weather station, (2) a micro-computer that acquires the data from the weather station, (3) a model to convert weather data to a meaningful animal stress response indicator, (4) and an output device to display response predictions. Each of the components is described in the sections that follow.

Weather Station

The commercial weather station (Vantage PRO, Davis Instruments, Hayward, Calif.) was chosen based on price, performance, weather parameters monitored, and ability to export real-time data. Additionally, the application required that the weather station has a wireless option so that the data collection/readout device could be located remote from the weather monitoring site. The commercial weather station provides real-time, on-site measures of t_a, RH, SR, and WS that are updated on 10-s intervals. The wireless option allows the weather station to be located up to 30 m from the display unit; repeaters are available to increase this distance. The weather station, as used for the LSM system, costs approximately $700.

Micro-Computer

A micro-power small-board computer (TFX-11; Onset Computer Corp., Pocasset, Mass.) was used as the data collection device and data processor. The TFX-11 specifications include: small size (8.1 × 5.33 × 1.27 cm), built-in real-time clock, 512k of EEPROM, 128k of battery backed RAM, and two serial communication ports. These specifications met the requirements for the LSM. The TFX-11 is equipped with 0.1-in. headers for electrical connection to an interface board. A user-developed interface board was designed based on a prototype unit using a CAD-printed circuit board design program. All communication lines connect to the TFX-11 through the interface board. The system is shown schematically in figure 1 with the complete LSM system shown in figure 2. The LSM micro-controller and circuit board cost approximately $400 for the components.

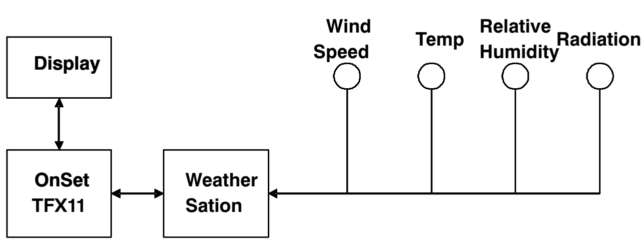

Figure 1. Schematic of livestock safety monitor with weather measure inputs from a commercial weather station and cattle respiration rate estimate (output) as an indicator of level of thermal stress.

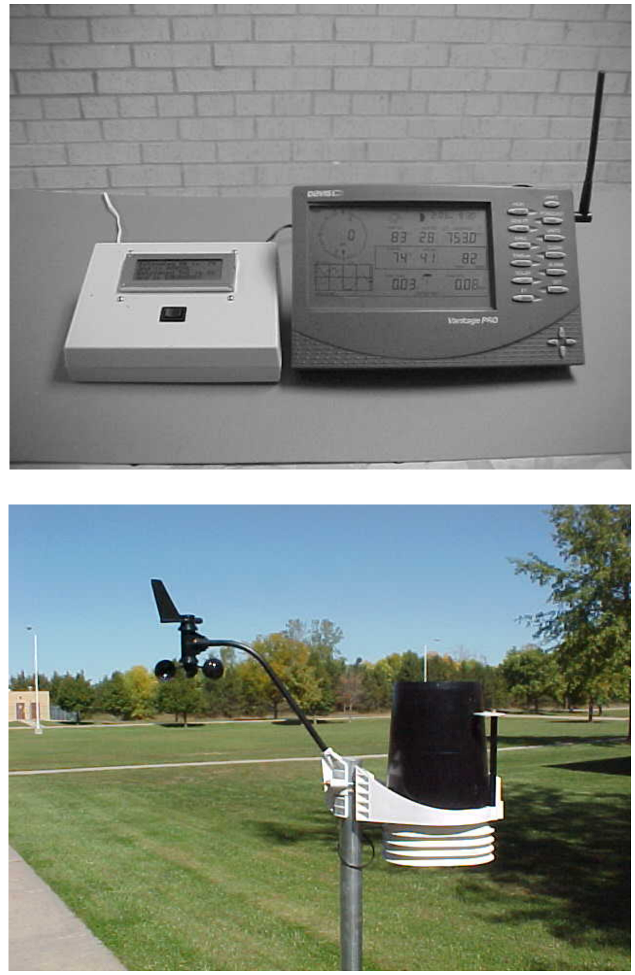

Figure 2. Pictures showing the Davis weather station with the LSM (left) and the weather sensors (right).

Software and Animal Response Model

Programming the TFX-11 is accomplished via a development program from Onset Computer Corporation. The instruction set for the TFX-11 is a modified BASIC programming language. Onset Computer provides specialized commands that perform routine tasks such as serial communication commands and time functions. The LSM program was written to collect the serial weather stream of data coming from the Davis weather console. Once the data block was collected the non-essential weather parameters are filtered out so that only t_a, RH, SR, and WS remain. Those four parameters are used to generate an estimated RR for current weather conditions.

The equation that predicts RR was developed from a study conducted during the 2001 summer, and reported in Eigenberg et al. (2005). The study used automated RR monitors (Eigenberg et al., 2000) on eight individually-penned MARC III (crossbred Pinzgauer, Red Poll, Hereford, Angus) steers in conjunction with an on-site weather station (both collecting data on 15-min intervals). Based on that study (Eigenberg et al., 2005), a multiple linear regression relationship was developed for ambient temperatures greater than 25°C.

$$RR = 5.1*t_a + 0.58*RH - 1.7*WS + 0.039*SR - 105.7 \quad (1)$$

where

RR = the respiration rate of cattle (breaths per min)

t_a = ambient temperature (°C)

RH = relative humidity (%)

WS = wind speed (m s^{-1})

SR = solar radiation (watts m^{-2})

Output

A spreadsheet was used to establish stress thresholds based on respiration values. The spreadsheet was run using the equation for THI using known threshold values for ranges of temperature and humidity. Solar radiation was fixed at a value of 800 Wm^{-2} with WS set at 0 m s^{-1}. These values were chosen to represent values of SR and WS consistent with stressful conditions. The relative humidity was allowed to range between 30% to 50%, and dry-bulb temperature ranged between 25°C to 40°C, while keeping SR and WS fixed. Equation 1 was then used to generate values of RR that corresponded to established THI values. Table 1 shows RR values associated with THI thresholds of Normal, Alert, Danger and Emergency using the described method. The derived values serve as estimates of potentially stressful conditions for cattle under hot conditions. The output device of the LSM displays both the predicted RR and the heat stress category to provide the producer real-time information, updated on 10-s intervals.

Validation Study

Two separate datasets were used to test the equation used in the LSM. The first dataset was collected during a study conducted during the summer of 2002 and 2003 and was summarized by Brown-Brandl et al. (2005a). Four pens (each pen contained one of the following breeds: Angus, MARC III, Gelbvieh, or Charolais) of finishing cattle (each pen held 32 heifers) were observed two times per day over a period of six weeks in 2002 and nine weeks in 2003. Ten animals were randomly selected at each observation time. Respiration rates of the selected cattle were manually measured by counting flank movements. At the time of measurement, climate variables (t_a, RH, SR, and WS) were measured and RR was estimated, using equation 1. The observed RR of healthy (never treated for pneumonia) dark-hided (MARC III and Angus) animals were compared to the estimated RR based on weather parameters as applied to equation 1. The comparison was completed using a linear regression model running under PROC GLM in SAS (1999).

The second dataset was collected during a study conducted in Australia in the summer of 2003 and reported by Eigenberg et al. (2004). Six individually outdoor penned Angus heifers were fitted with automated respiration monitors (Eigenberg et al., 2000) and were rotated through pens either equipped with shade or having no shade available. Respiration rates were electronically determined every 15 min and offloaded at the end of each treatment period. Climate variables were also collected on 15-min intervals and applied to equation 1 estimates of RR. The estimated and electronically measured RR was compared using a linear regression model running under PROC GLM in SAS.

Table 1. THI thresholds related to equation 1 for the assumptions of solar radiation of 800 watts m^{-2} and relative humidity range of 30% to 50%, as well as a wind speed of 0 m s^{-1} (Eigenberg et al., 2005).

Threshold	THI	RR Based on Equation 1
Normal	< 74.0	Up to 90 breaths/min
Alert	> 74.0 to < 79.	90 to 110 breaths/min
Danger	> 79.0 to < 84.	110 to 130 breaths/min
Emergency	> 84.0	130 and higher breaths/min

Results

The association of the Brown-Brandl and Eigenberg data with the predicted RR results was determined using PROC GLM shown as equations 2 and 3, respectively. The Brown-Brandl dataset includes Angus and MARC III heifers, and the Eigenberg data is based on Angus heifers.

$$\text{Estimated RR} = 1.02*\text{actual RR} - 32.5, \quad \text{with an } R^2 = 0.52 \; n = 2008 \quad (2)$$

$$\text{Estimated RR} = 1.09*\text{actual RR} - 8.1, \quad \text{with an } R^2 = 0.51 \; n = 3721 \quad (3)$$

Equations 2 and 3 demonstrate good predictive capability with a slope of nearly one. The correlation coefficients indicate that approximately 50% of the variability in RR is described by the selected weather variables in these experimental studies. Other factors that contribute to animal RR include health status, temperament, breed and condition score (Brown-Brandl et al., 2003, 2005b). Individual animal characteristics become important considerations in precision tactical management decisions as the more severe threshold categories are reached. High-risk animals (health history of respiratory ailments, dark hides, cattle near finished weights) should be identified in preparation of a heat wave.

The LSM has been installed at producer sites in north central and south west Nebraska, and at a feedlot in east central Australia (University of Queensland, Gatton), as well as our own feedlot research site in south central Nebraska (USMARC). Feedlot operator reaction to the on-site real-time heat stress information has been favorable; the operators reported that the LSM provided them with a valuable indication of stressful conditions, as well as serving as a training tool for feedlot cattle handlers. The LSM has performed reliably, with only standard maintenance to the weather station sensors.

Conclusion

This work describes the development and testing of a livestock safety monitor, which may be used as a tool to alert feedlot operators of adverse hot weather conditions. Independent validation, based on two separate studies, has shown estimated RR to be a good indicator of actual environmental conditions at the feedlot. Individual variability of RR can be great; however, the use of RR as a response measure for predicting overall stress of feedlot cattle has proven valuable. Feedlot managers have found the LSM to be a beneficial tool in tactical decisions related to animal well-being. At risk animals can be provided prescribed management options to minimize high heat impact as indicated by an on-site, realtime livestock monitoring system.

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